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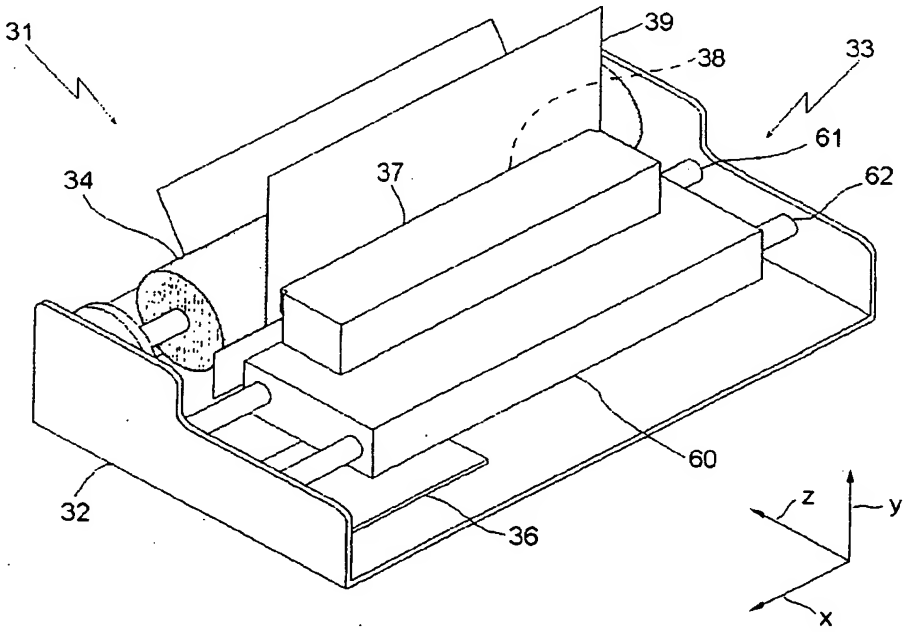
(54) Title: PRINTING DEVICE WITH PARALLEL TYPE INK JET PRINTHEAD



(57) Abstract: A printing device (33) has an in-line ink jet head (37), comprising a plurality of nozzles (38) arranged side by side in front of a printing sheet (39), in turn longitudinally movable for an in-line printing of the nozzles. The head (37) is open to transversal motion with respect ot the print medium (39) associated with the longitudinal motion of the sheet (39), over an extension and with a control of the actuations of the nozzles such as to produce a masking effect of dots unprinted due to a malfunctioning of one or more nozzles and/or an increase of the equivalent printing definition.

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PRINTING DEVICE WITH PARALLEL TYPE INK JET PRINTHEAD

Technical Field

This invention relates to a printing device with parallel or "in-line" type ink jet head, used for forming black or colour images on a print medium.

Background Art

More specifically, the invention concerns a printing device with parallel or in-line ink jet head, comprising a plurality of nozzles according to the introductory part of claim 1.

The printing device may be used in general purpose printers or for photographic reproductions, in labelling machines, or in similar machines. Printing is effected on a medium consisting of a sheet of paper, or plastic, or other material.

An ink jet printhead, of the thermal type for instance, provides for a plate with one or more rows of nozzles, an actuating assembly with resistors associated with the nozzles and the emission of droplets of ink perpendicularly to the plate. This is widely known, and will not therefore be described in detail herein.

The current technology tends to produce heads with high density of nozzles for a printing definition of more than 600 dpi (dpi = dots per inch), a high work frequency ($\geq$ 10 kHz) and producing ever smaller droplets ($\leq$ 10 pl). Addressing techniques have also been developed that modulate various dots on the same print location (multidrop), obtaining effects similar to those of an enhanced printing definition. This is particularly widespread in colour heads, and requires compact size actuators and hydraulic circuits, precision of assembly and stringent tolerances.

Printing devices with parallel or in-line type ink jet head produce printouts in a short space of time, in relation to the number of dots comprising the image, and are compact. Furthermore, on account of the fixed head, these devices have a lesser number of moving parts than the devices that employ a serial type ink jet head.

A common problem shared by all printing devices based on ink jet technologies concerns the fact that operating defects of the individual nozzles are intrinsically evident on the printed sheet.

In printing devices with a serial head, to obtain high quality images, "shingling" is used, by which is meant methods in which the sheet is fed by an amount less than the height of the head and in which a final line of print is obtained with various overlapping passes. An elementary row is not printed by one nozzle associated therewith but is composed by dots of ink emitted by nozzles in different parts of the head. The advantage lies in the fact that the

effect of dots missing due to a defective nozzle is lessened over various rows, and the visual disturbance is reduced.

In printing devices with in-line ink jet head, any defect of a nozzle is particularly obvious on the printed sheet, where the printing positions on the sheet are unambiguously associated with the individual nozzles, since all the elementary rows into which an image is broken down and on the same print grid, the dot associated with the faulty nozzle is missing. This is manifested in the appearance of an unprinted, and therefore clearer, line over the entire height of the image.

The unique association between the printing positions and the nozzles of an in-line head limits definition of the image to definition of the nozzles.

Disclosure of the Invention

The object of this invention is to produce a printing device with "in-line" ink jet head, in which the faulty operation of a nozzle has minimal visual disturbance on the printed sheet.

Another object is to obtain high definition printing using an in-line head having a density of nozzles with lower definition, or to obtain printing of average definition and high speed with a nozzle density lesser than that of the printable dots.

These objects are achieved by the device of the invention which allows for an alternating transverse motion between head and print medium simultaneous with the longitudinal motion of the medium, according to the characteristic part of claim 1.

Another object of the invention is to provide a printing device with ink jet head that has a good dot definition and which is suitable for miniaturization, in particular for integration in digital cameras or in associated compact accessories.

A further object of the invention is to obtain a printing device with an in-line ink jet head suitable for miniaturization and autonomous feeding and in which the peak currents absorbed by the actuators of the row of nozzles in the head are minimal.

These objects are achieved by the device of the invention, according to the characteristic part of claim 13.

In photographic applications, the tanks for the different colour inks may be applied to the medium of the head and be easily interchangeable. Alternatively or, in combination with, the tanks may be unconstrained from the head when the head is subject to the alternating motion, according to the characteristic part of claim 17.

These and other objects, characteristics and advantages of the invention shall become apparent from the following description of an embodiment, provided by way of non-

restrictive example, with reference to the accompanying drawings.

Brief Description of Drawings

Fig. 1 Represents a schematic view of a printer that employs a printing device with parallel or in-line type ink jet head, according to the invention;

Fig. 2 is a partial schematic view of an in-line ink jet head;

Fig. 3 represents a block diagram of control of the printing device according to the invention;

Fig. 4 represents a variant of a printing device with ink jet head according to the invention;

Fig. 5 is a diagram of dots printed by a device according to the known art;

Figs. 5a, 5b and 5c represent different diagrams of dots printable by a printing device of the invention, in accordance with a first methodology;

Fig. 6a represents a diagram of dots printable by a device of the invention, in accordance with a second methodology;

Fig. 6b represents a variant of the diagram of printable dots of Fig. 6a;

Fig. 7 is a diagram of an in-line ink jet head according to the invention; and

Fig. 8 represents a diagram of operation of the printing device according to the invention.

Best mode for Carrying Out the Invention

Depicted in Fig. 1 is a printer 31 comprising a fixed structure 32 and a printing device 33.

The device 33 includes a contrast roller (or platen) 34, electronic control means 36 and a colour, parallel or in-line type printhead 37. The head 37 is arranged in front of the platen 34 for its full length and comprises a plurality of nozzles 38 suitable for actuation by corresponding resistors. The platen 34 supports a print medium which consists of a sheet 39 of paper, plastic or other material and is fed by a step motor 41 (Fig. 3) by way of the electronic means 36 for defining the elementary lines of the image.

Also shown in Fig. 1 are the reference axes X, Y and Z: The X axis is horizontal in use, i.e. parallel to the axis of the platen 34 and to a transverse axis of the head 37; the Y axis is vertical, i.e. parallel to the direction of motion of the medium 39 during the line feed function; and the Z axis is perpendicular to the X and Y axes, parallel to the direction of emission of the ink droplets by the nozzles 38.

With reference to Fig. 2, the nozzles 38 of the head 37 are made on a nozzles plate 51, arranged in three rows 56, 57, 58 parallel to the X axis, respectively associated with the colours yellow, magenta and cyan. The distance between the end nozzles of a row, indicated

M, is associated with the effective width for in-line printing.

The nozzles plate 51 (Figs. 2 and 7) is, for example, of the type described in the patent EP 0 652 107, made up of six printing modules 59, having a distance H between the end nozzles of 25.4 mm (1 inch) in order to form the distance M. Each module 59 contains 600 nozzles 38 kept apart by a distance "p" of 42 μm (1/600 of an inch) and a definition of 1/600". Each colour row 56, 57, 58 is made up of pairs of staggered modules in such a way as to have 1200 nozzles, giving a printing width of 50.8 mm.

In a printer with in-line head, the failure of a nozzle to function is apparent as a lack of colour dots arranged according to a vertical line, so as to alter uniformity of the printout.

In figure 5 an image is shown obtained according to the known technique of activation of all the nozzles in the row 56, for a droplet of, by way of example, 20 pl. and in the case where one of the nozzles, for instance nozzle 56b in printing position "n", does not work or is defective. Due to the continuity of the missing dots, the defect stands out clearly with respect of the adjacent printing positions "n-1", "n-2", "n+1" and "n+2" and is therefore unacceptable.

In accordance with this invention, the head 37 (Fig. 1) is made to move with respect to the sheet 39, making allowance for extra nozzles 38 with respect to those necessary to perform a line of print according to the known technique of figure 5. Movement and actuation of the nozzles are regulated individually in a reciprocal relationship and with respect to the sheet feeding motion in such a way as to conceal possible unprinted dots on the sheet and/or increase the equivalent print definition.

According to a first embodiment, the volume of the droplets emitted by the nozzles remains the same but each line is printed in several passes, activating the nozzles with permutations consistent with the number of passes. A defect of one nozzle is diluted over a number of columns and for an extension depending on the number of passes and on the width of the oscillations.

In this way a multi-pass mode is achieved which, by applying a shingling form of masking, reduces the visual disturbance. Shown in the drawings of Figs. 5a, 5b and 5c are the dots formed by a generic nozzle in relation to a series of printing positions, relative to shingling modes with 2, 3 and 4 passes or levels, in the case of continuous feeding of the sheet 39.

In accordance with a second embodiment, each grid associated with the printing positions is sent various ink droplets of lesser volume than in the previous case

(multidrop/multilayer). In addition, the nozzles 38 may be controlled in relation to the alternating motion between the head 37 and the sheet 39 so as to address the droplets to different areas of the grid.

By way of example, for a volume of elementary droplets equal to one quarter of the volume a single droplet, the droplets may be freely addressed to four areas of the grid. The grid may therefore be covered by means of a quadruple form of dot addressing, giving an equivalent definition of approx. 1200 X 1200 dpi or, to use a different terminology, a definition of 600 X 600 dpi with four-level modulation. The head 37 also has allowance for more nozzles 38 to cover all the dots of the grids associated with the end positions of the line of print.

Fig. 6a illustrates an example of printing with four-level modulation, volume 5 pl and an oscillation width of 5p in the two directions. The result is an automatic shingling effect for the missing or defective dots. Each grid has differently coloured dots and the number of extra nozzles is ten.

By slowing down or accelerating sheet feeding and increasing or decreasing the oscillation width, the grid may contain more or less dots. In the case of a printing definition of 300 dpi, for four dots in the grid, heads of 20 pl. are suitable and for eight dots in the grid heads of 10 pl.

Obviously, for a like maximum jet frequency of the nozzles, shingling mode and modulation mode lower the overall printing speed. On account of parallelism of the nozzles, printing speed is high at any rate while the considerations regarding noise level and acoustic disturbance linked with the oscillation frequency of the head or sheet apply. Therefore, if the sheet feeding motion is lowered, the frequency is lowered to under 40 Hz.

The shingling of the first embodiment and the multi-level modulation of the second embodiment may be suitably combined to give different equivalent definitions and different levels of defect masking with a scanning motion amplitude that varies between one and sixty-four times the step "p".

The diagram of figure 6b shows an example of printing with shingling and four-level modulation and alternating motion amplitude equal to 9p in the two directions. The number of extra nozzles is eighteen and the missing dot of a nozzle is distributed over a wide area and with a density that renders visual disturbance imperceptible.

Table 1 below shows various application solutions by droplet volume, number of addressable dots, shingling levels, number of extra nozzles and frequencies of oscillation

between head and sheet and other significant parameters.

TABLE 1

Droplet volume (pl)	Dots/ pixel	Equivalent definition	Shingling level	Extra Nozzles	Oscillation Frequency (Hz)	Feed rate. (cm/s)	Printing mode	Jet freq. (KHz)	Amplitude of oscillat. +/-(um)
20	1	600X600	0	0	0	33.6	NORMAL	8.0	0
20	2	1200x600	2	6	500	8.4	SHINGLING	4.0	126.9
20	3	1200x900	3	8	222	3.7		2.7	169.2
20	4	1200x1200	4	10	125	2.1		2.0	211.5
20	6	1800x1200	6	14	56	0.9		1.3	296.1
20	8	2400x1200	8	18	31	0.5		1.0	380.7
20	12	2400x1800	12	26	14	0.2		0.7	549.9
10	2	1200x600	0	6	1500	25.2	2-level mod.	12.0	126.9
10	4	1200x1200	2	10	375	6.3	2-level mod. + SHINGLING	6.0	211.5
10	6	1800x1200	3	14	167	2.8		4.0	296.1
10	8	2400x1200	4	18	94	1.6		3.0	380.7
10	12	2400x1800	6	26	42	0.7		2.0	549.9
10	16	2400x2400	8	34	23	0.4		1.5	719.1
5	4	1200x1200	0	10	1125	18.9	4-level mod.	18.0	211.5
5	8	2400x1200	2	18	281	4.7	4-level mod. + SHINGLING	9.0	380.7
5	16	2400x2400	4	34	70	1.2		4.5	719.1
5	24	3600x2400	6	50	31	0.5		3.0	1057.5
5	32	4800x2400	8	66	18	0.3		2.3	1395.9

It is clear from the table that increasing the number of extra nozzles requires an increase in the amplitude of oscillation and a decease in the frequency and a slowing down of the printing speed, but allows an ever larger number of dots to be addressed inside each single grid, by increasing the modulation levels (dots per grid) and as a result the equivalent printing definition.

The limit that defines the passage between increasing the modulation/definition levels and shingling is given upon reaching full printing saturation (volume of ink/pixel). For instance, for a grid of 600x600 dpi this limit is given by 20pl and shingling masking rules out the higher definition levels.

The convenience of resorting to high levels of shingling lies in the fact that printing uniformity increases considerably and that a low oscillation frequency (< 20Hz) must be selected at any rate. The gain in quality is obtained therefore for like printing time merely from a greater number of lateral nozzles and a greater oscillation amplitude.

Similar consideration may be made about heads of lower definitions (300 dpi and 150 dpi), with which it is possible to reach, at the same printing speed, equivalent definitions highly similar to those of heads of higher definitions.

Structurally, the head 37 is supported by a carriage 60 which can effect a scanning movement of the desired width with respect to the platen 34. The carriage 60 is suitable for sliding on guides 61 and 62 and its movement is controlled, for example, by means of a cam (not depicted in the drawings) suitably connected with the motor 41 and in sync with the motion of the sheet 39.

Fig. 8, in relation with figure 6a, depicts on the X axis the oscillation time of the carriage 60 and on the Y axis its displacement according to a law of linear motion. Feeding of the sheet 39 in the direction of the Y axis is equal to p/4 (1/2400") for each pass and the relative scanning of the carriage in the direction of the X axis is equal to 5/4p. Excitations of the nozzles 38 occur at constant intervals "t" equal to 1/16 of the period "T", corresponding to a double pass of the carriage.

The law of motion of the carriage may be sinusoidal type and actuation of the nozzles may be slave driven, with feedback, by a carriage linear position encoder or by other systems without feedback, which ensure that the dots are equidistant and that there is alignment of the printing positions of the different elementary line feeds.

The circuit 36 comprises, for example, a controller unit 71, a driver 72 for the motor 41 and a driver 73 for the actuators of the head 37. The controller 71 controls the drivers 72 and 73 and performs, on each pass, the maskings and permutations of the commands of the nozzles, associated with the oscillating movement of the carriage and with the printing mode.

The unit 71 also provides the timing for command of the nozzles and synchronization of these commands with the line feed movements. Carriage oscillation frequency is selected low, between 5 and 40 Hz and preferably less than 20 Hz. In this way, as well as lowering the noise emitted by the carriage when moving, the printing time may be considered instantaneous with respect to the movements under way and there is a wide dispersion of missing dots.

According to another characteristic of the invention, the control circuit 36 excites the resistors actuating the head 37 in sequential groups in order to minimize current peaks and allow use of an independent battery power supply.

As a limit example, for a single colour of 1200 dots, 30 blocks are provided of 20

conventionally even resistors and 30 blocks of 20 odd resistors and the resistors are excited in twos, even and odd ones, for a time of 2.5 μs. Selection of the 1200 nozzles of each primary colour therefore requires 1.5 ms. and, for a peak resistor absorption value of 0.1A, the peak current needed to excite the 6 resistors of the three primary colours is approximately 0.6 A for a head of 4 pl.

The scanning movement of the head 37 does not substantially worsen the working characteristics of the printer 31. For a scanning frequency of 10 Hz, it takes 25 ms to travel the distance equal to ¼ of the oscillation path of the carriage 60. The time needed to write with 1200 nozzles is therefore 16 times less that the time needed to travel this distance and accordingly there are no drawbacks regarding deposition of the ink on the sheet.

Shown in figure 4 is a variant, designated with the numeral 76, of the printing device of the invention. In this variant, the printing sheet, here designated with the numeral 77, is engaged between pairs of feeding rollers 78-1, 78-2 and 79-1, 79-2 parallel to the X axis and to the transversal axis of the head 37.

The rollers 78-1, 78-2 and 79-1, 79-2 are driven by a relative step motor and provide the feeding movement of the sheet 77 on the Y axis. Again in this case, there is oscillating movement between head 37 and sheet 77.

In a first solution, the ink jet head 37 is fixed and the oscillating movement is obtained by moving the four rollers along their axis together with the sheet 77. In a second solution, the four rollers are fixed along their axis and the head 37 is made oscillate with respect to the sheet 77.

The printing device 76 is suitable for miniaturization. It may be used to advantage in integration with digital cameras or in relative, compact accessories for printing adequately-sized photographs (10 x 15 cm). In these cases, in fact, the number of nozzles is low and the times needed to invert motion are perfectly acceptable.

In the photographic applications, the tanks for the different colour inks can be applied by pressure-fit into the head support and are easily interchanged, as indicated in the above-mentioned patent EP 0 652 107.

According to another aspect of the invention, where the head 37 is open to movement, the three ink tanks are in flexible connection, for example through bellows, with the rows of nozzles 38. Alternatively or in combination, the tanks are in a fixed position and the head remains released from the tanks, minimizing inertia of the moving parts.

In association with miniaturization, the device 74 is also open to feeding with an

autonomous power supply. Excitation of the resistors actuating the head 37 in sequential groups in fact renders minimal the peak currents absorbed by the actuators of the nozzles, guaranteeing the batteries supplying power an acceptable life.

Naturally, while the principle of the invention remains unaltered, the embodiments and the details of manufacture of the printing device with ink jet head may be abundantly varied with respect to what has been described and illustrated merely by way of non-restrictive example, without departing from the scope of the invention.

CLAIMS

1. Printing device (33. 76) with in-line ink jet head (37), comprising a plurality of nozzles (38) arranged side by side in front of a print medium or sheet (39, 77) and associated with corresponding grids in reference printing positions, and in which said sheet is longitudinally movable for the definition of various lines of print, said device being characterized in that it allows for an alternating transverse motion between the head (37) and the sheet (39, 77) coinciding with the longitudinal motion of the above-mentioned sheet and for a permutation in the actuation of the nozzles associated with said printing positions for masking possible unprinted dots (56b) on said sheet and/or for obtaining numerous dots in the said grids thereby increasing the printing definition with respect to that of said nozzles.

2. Device according to claim 1, characterized in that said head has extra nozzles, the number of which depends on amplitude of the above-mentioned motion.

3. Printing device according to claim 1 or 2, characterized in that said alternating motion extends for a total amplitude of between, in the two directions, one and sixty-four times the step of the nozzles.

4. Device according to any of the preceding claims, characterized in that said alternating motion has a frequency of between 5 and 40 Hz.

5. Printing device according to claim 4, characterized in that said frequency is less than 20 Hz.

6. Device according to any of the preceding claims, characterized in that said permutation is such as to maintain, for each permutated nozzle, the alignment of the grids associated with each printing position.

7. Printing device according to any of the claims from 1 to 6, characterized in that said nozzles are activated in intermediate printing positions with respect to the reference printing positions, increasing the transversal definition of the printed dots with respect to the density of the nozzles.

8. Device according to any of the preceding claims, characterized in that the alternating motion is obtained by displacing said sheet (77).

9. Device according to any of the claims from 1 to 7, characterized in that the alternating motion is obtained by displacing said head (37).

10. Printing device according to any of the preceding claims, characterized in that it is of miniature dimensions for application in integration with digital cameras or in relative, compact-sized accessories for the printing prevalently of photographs.

11. Device according to any of the preceding claims, characterized in that it is open to an autonomous power supply and in that said nozzles are activated by relative actuators driven in sequential groups to minimize the current peaks absorbed by said autonomous power supply.

12. Device according to any of the preceding claims, characterized in that said nozzles are actuated according to a shingling type, multipass mode.

13. Device according to any of the preceding claims, characterized in that said nozzles are actuated according to a modulation type multipass mode.

14. Printing device (76) with in-line ink jet head (37), comprising a plurality of nozzles (38) arranged side by side in front of a longitudinally movable print medium (77), said device being characterized in that the print medium (77) is open to transverse motion with respect to the head (37) in association with its longitudinal motion, said device being suitable for integration with a digital camera or with a relative accessory for the printing prevalently of photographs taken by said camera.

15. Device according to claim 14, characterized in that said nozzles (38) are associated with relative reference printing positions, and wherein said device allows for a permutation of the actuation of the nozzles associated with said printing positions for masking unprinted dots (56b) on said medium (39, 77) following a malfunctioning of one or more nozzles.

16. Printing device according to claim 14 or 15, characterized in that it is open to autonomous power supply and in that said nozzles are activated for ink jet emission by actuators driven in sequential groups for minimizing the current peaks absorbed by the autonomous power supply.

17. Printing device according to claim 14 or 15 or 16, characterized in that it comprises tanks for the various colour inks fittable by applying pressure.

18. Printing device (76) with in-line ink jet head (37), comprising a plurality of nozzles (38) arranged side by side in front of a longitudinally movable print medium (77) and tanks for the ink in connection with said nozzles, said device being characterized in that the head (37) is open to transversal motion with respect to the print medium (77), and the tanks for the ink are in flexible connection with the rows of nozzles, for example by means of bellows, unconstrained to movement of the head.

19. Printing device (33) with parallel ink jet head substantially as described and with reference to the drawings.

Fig.1

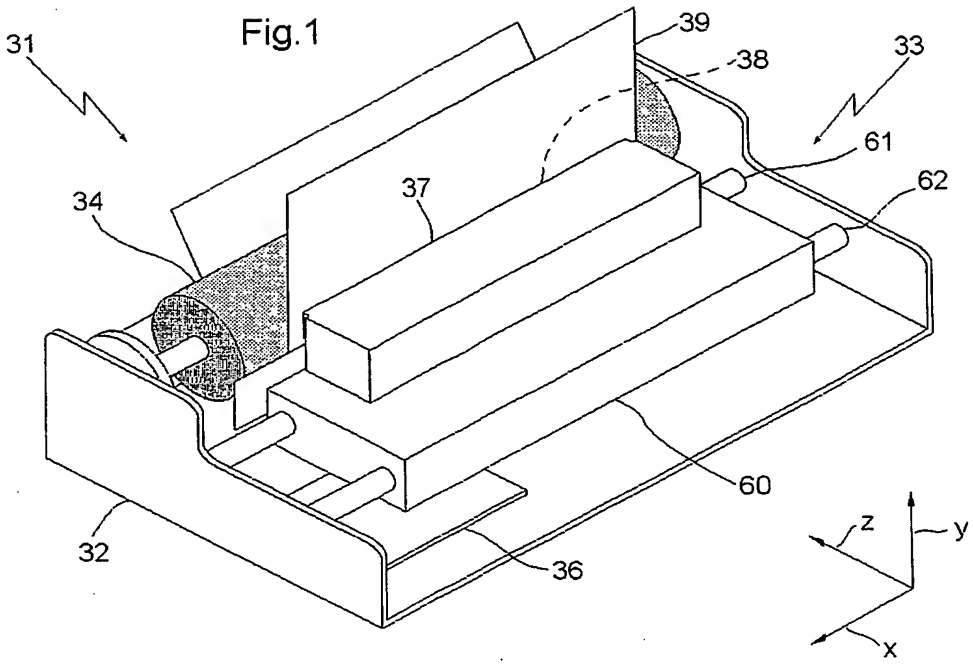
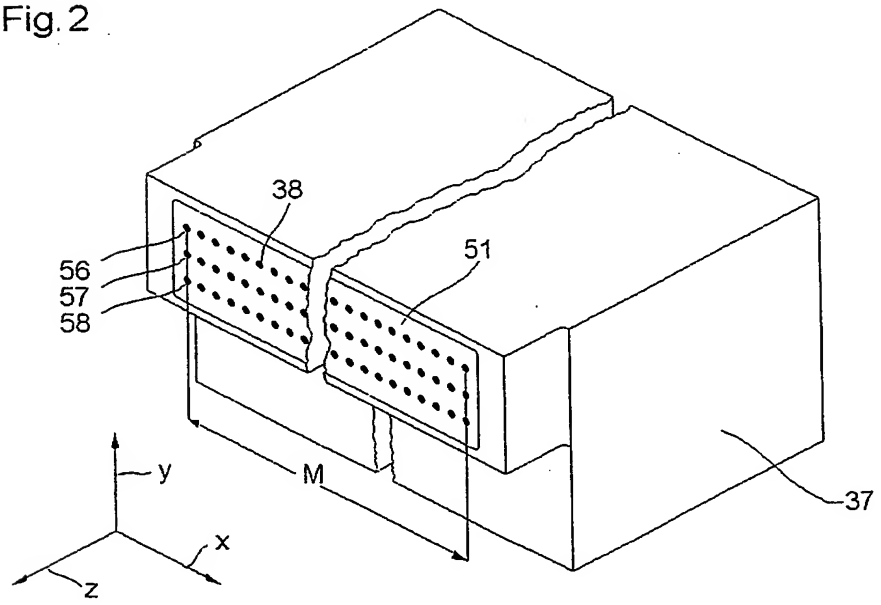


Fig. 2



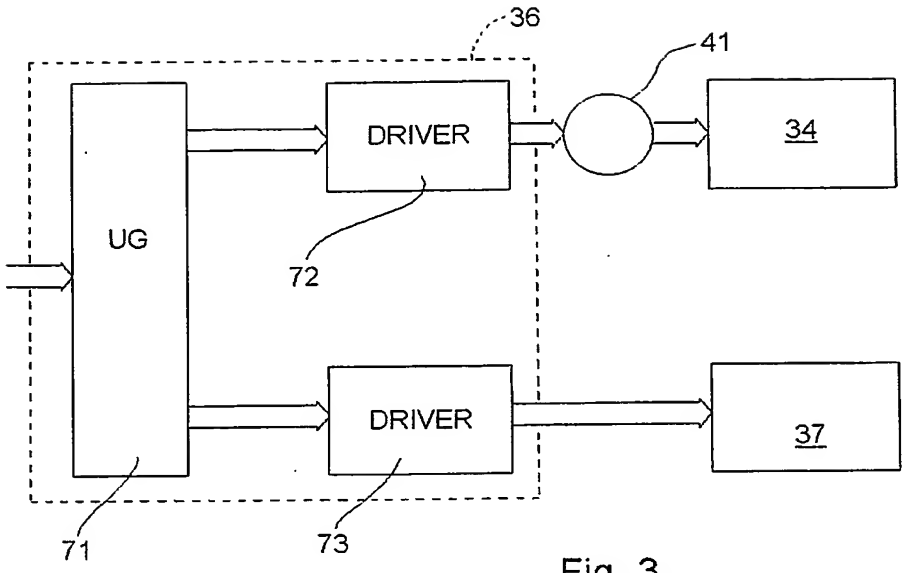

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Fig. 3

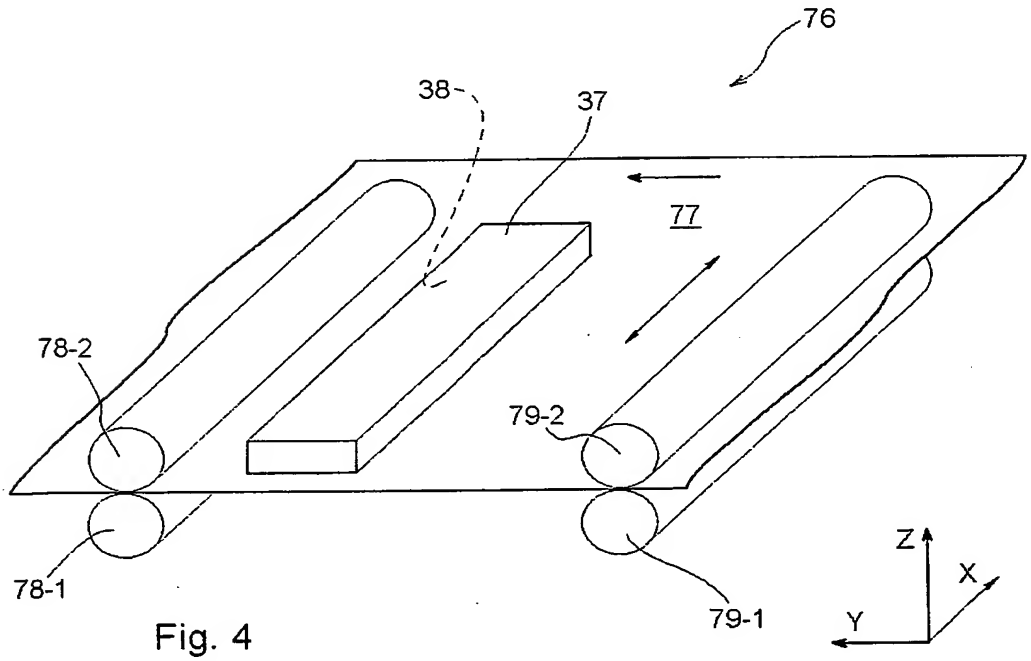
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Fig. 4

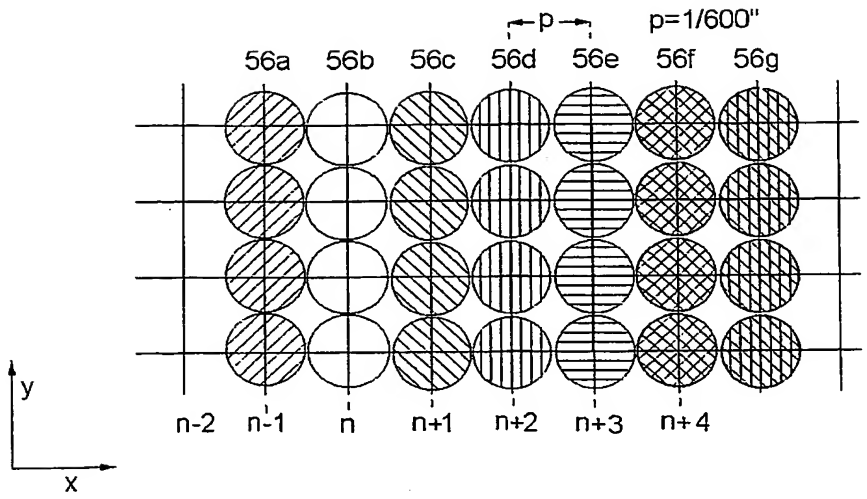

Fig. 5

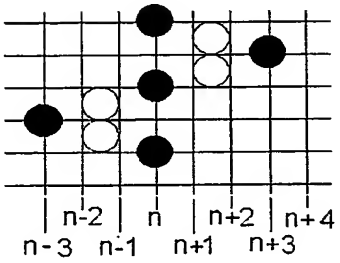

Fig. 5a

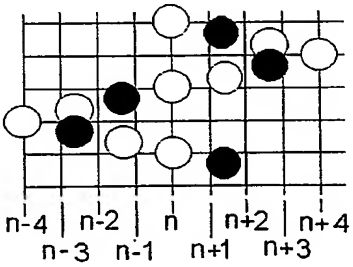

Fig. 5b

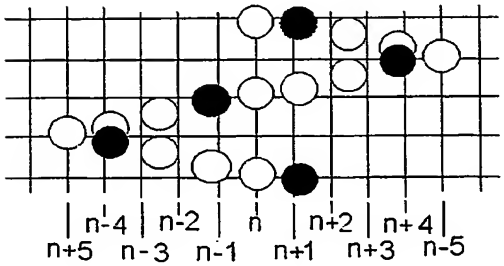

Fig. 5c

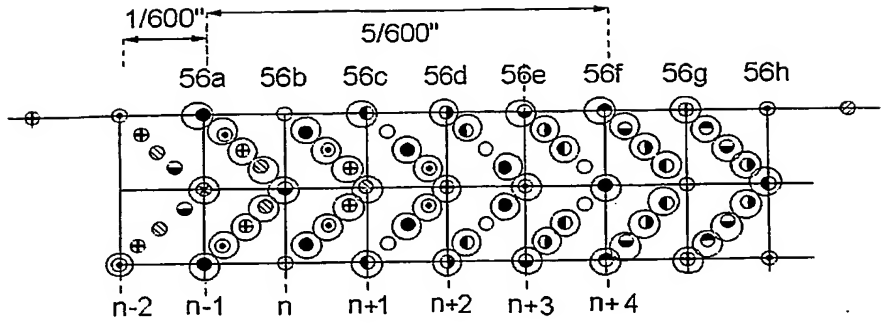

Fig. 6a

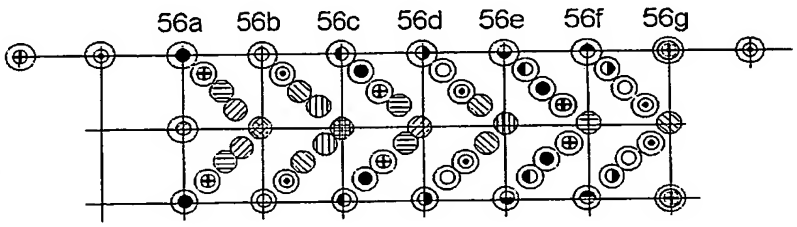

Fig. 6b

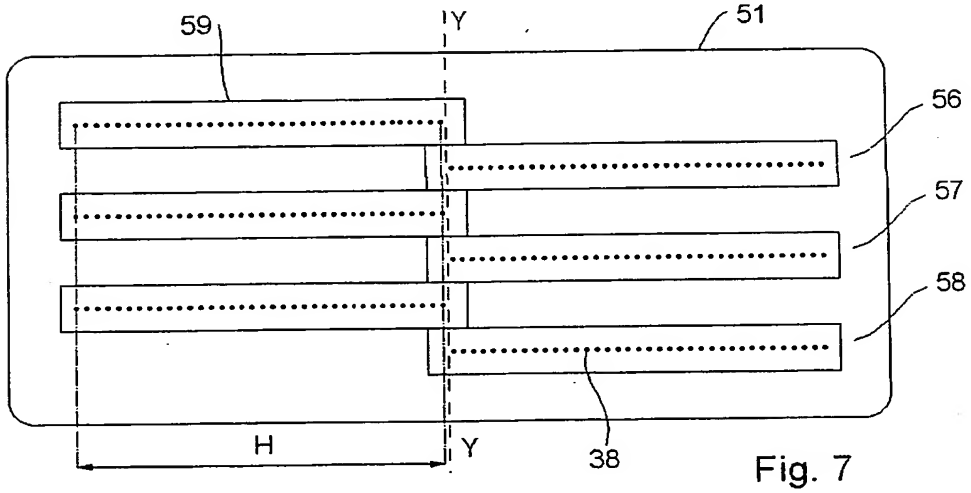

Fig. 7

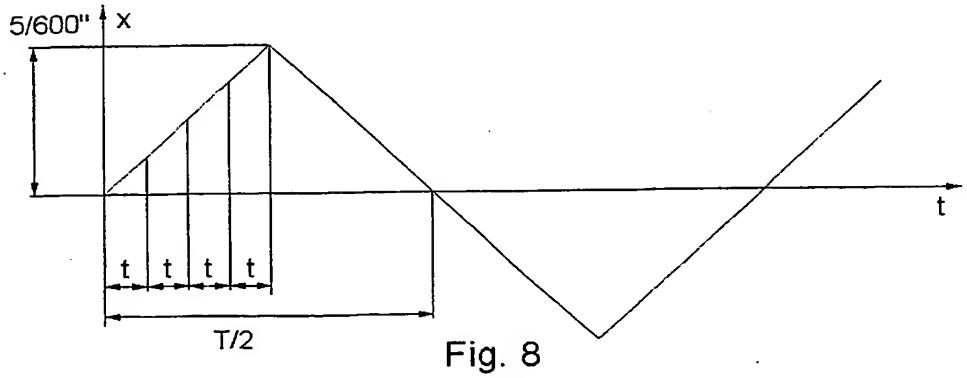

Fig. 8

INTERNATIONAL SEARCH REPORT

International Application No
PCT/IT 02/00442

A. CLASSIFICATION OF SUBJECT MATTER
IPC 7 B41J2/515 B41J2/175

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
IPC 7 B41J

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)
EPO-Internal, PAJ, WPI Data

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category °	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 6 217 148 B1 (ADLER URI ET AL) 17 April 2001 (2001-04-17) the whole document	1-19
X	EP 0 963 854 A (KONISHIROKU PHOTO IND) 15 December 1999 (1999-12-15)	1-17,19
Y	column 3, line 56 -column 4, line 48 column 6, line 22 - line 29 column 12, line 29 - line 49; figure 9	18
X	US 4 223 323 A (BADER LEONHARD ET AL) 16 September 1980 (1980-09-16) column 1, line 62 - line 53; figures 1,3	1-19
X	EP 0 023 433 A (XEROX CORP) 4 February 1981 (1981-02-04) page 7, line 20 - line 28; figure 1	1-19

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[X] Further documents are listed in the continuation of box C.

[X] Patent family members are listed in annex.

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Date of the actual completion of the international search	Date of mailing of the international search report
24 October 2002	06/11/2002

Name and mailing address of the ISA	Authorized officer
European Patent Office, P.B. 5818 Patentlaan 2 NL – 2280 HV Rijswijk Tel. (+31–70) 340–2040, Tx. 31 651 epo nl, Fax: (+31–70) 340–3016	Axters, M

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INTERNATIONAL SEARCH REPORT

International Application No
PCT/IT 02/00442

C.(Continuation) DOCUMENTS CONSIDERED TO BE RELEVANT

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